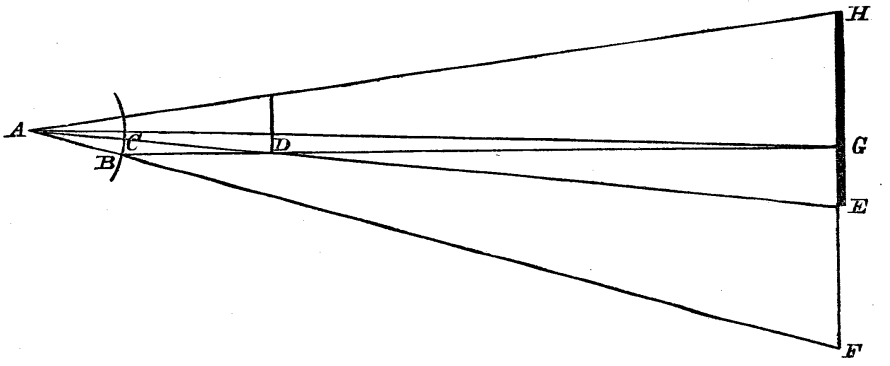
On the Determination whether the Corona is a Solar or Terrestrial Phenomenon. By George M. Seabroke, Esq.

It is my intention in this paper to attempt to show that, with the existing state of our knowledge of the corona, the theory set forth by Mr. Lockyer, that the corona is a terrestrial phenomenon, is quite possible, rather than to show that other theories are wrong,—and further to demonstrate how the question may be set at rest by observations on future eclipses. The points which present themselves are as follows:—

1. What are the facts with respect to the spectra of the corona seen in past eclipses?
2. What spectra ought we to obtain from the corona on the terrestrial theory during totality?
3. Are the spectra obtained from the corona in past eclipses reconcilable to those we ought to get on the above hypothesis?
4. What spectrum ought we to get from the corona after totality?
5. What spectrum ought we to get before totality on the following side of the Moon?
6. What difference will there be between the spectrum of the central portions of the corona and that of the distant parts during totality?

With regard to (1) during the Indian eclipse, Major Tennant writes,—"Directly I saw the whole Moon in the finder I set the cross-wires immediately outside its upper limb. By the time I got to the spectroscope the cloudy range seen in the photographs had vanished from the slit, and I saw a faint *continuous* spectrum. Thinking that want of light prevented my seeing the bright lines which I had fully expected to see in the lower strata of the corona, I opened the jaws of the slit and repeatedly adjusted by the finder, but without effect. *What I saw was undoubtedly a continuous spectrum, and I saw no bright lines.* There may have been dark lines of course, but with so faint a spectrum, and the jaws of the slit wide apart, they might escape notice." With respect to the American eclipse, Prof. Pickering, with an ordinary chemical spectroscope directed to the Sun's place during totality, saw a continuous spectrum with two or three bright lines; one "near E" and a second "near C." Prof. Young, while examining a part of the prominence at $+146°$, saw C, near D, a line at 1250 ± 20, and another at 1350 ± 20, and the 1474 K line very bright, but not equal to C and D_3; but he observed that the 1474 K line, unlike C and D_3, extended across the spectrum; and, on moving the slit away from the prominence, it persisted, while D_3 disappeared. He also believes that the two faint lines between it and D_3 behaved in like manner. On examining a prominence on the other side of the Sun, he observed nine lines and a faint continuous spectrum without any traces of dark lines in it.

As to the second point, let us find what spectrum we ought to obtain from a corona at a point on the Earth where the limbs of the Sun and Moon are in line; that is, where the eclipse is total, exactly.



Let A be a point on the Earth where Sun is eclipsed;
B C, limits of Earth's atmosphere;
D, the Moon;
H E, Photosphere of Sun;
E F, the apparent Corona.

Now, if the corona be terrestrial, the light producing it must be reflected or separated from the atmosphere within the triangle A B C.

Join B D and produce to G.

Then G is the most distant point from the limb on the Sun's disk, from which light is reflected to A by the atmosphere; and if the triangle E A F or angular extent of the corona from the Sun is given, we can find $\angle$ E A G.

The angles being small, $\frac{\angle \text{E A G}}{\angle \text{E A F}} = \frac{\text{G E}}{\text{E F}}$, approximately.

$$\text{G E} : \text{C B} :: \text{E D} : \text{D C}, \text{ therefore } \text{G E} = \text{C B}\,\frac{\text{E D}}{\text{D C}}, \qquad (1)$$

$$\text{and} \quad \text{E F} : \text{C B} :: \text{E A} : \text{C A}, \text{ therefore } \text{E F} = \text{C B}\,\frac{\text{E A}}{\text{C A}}, \qquad (2)$$

and E D = E A − A D, and A D being small in proportion to E A, E D may without great error be taken as equal to E A.

Dividing (1) by (2),

$$\frac{\text{G E}}{\text{E F}} = \frac{\frac{\text{E D or E A}}{\text{D E}}}{\frac{\text{E A}}{\text{C A}}} = \frac{\text{C A}}{\text{D C}} = \frac{\text{Height of atmosphere}}{\text{Dist. of Moon} - \text{height of atmosphere}},$$

$$\therefore \frac{\angle \text{E A G}}{\angle \text{E A F}} = \frac{\text{Height of atmosphere}}{\text{Dist. of Moon} - \text{height of atmosphere}},$$

$$\text{EAG} = \text{EAF}\,\frac{\text{Height of atmosphere}}{\text{Dist. of Moon} - \text{height of atmosphere}}.$$

If, for example, we now take

$$\text{EAF} = 30',$$

and Height of atmosphere = 100 miles,

and Dist. of Moon — ht. of atmosphere = 240,000 miles,

then $$\angle\,\text{EAG} = 30'\,\frac{100}{240{,}000} = 0''{\cdot}75.$$

Therefore, the only part of the photosphere available in this case for illuminating the atmosphere is a ring of photosphere $0''{\cdot}75$ in width, and from the figure it will be seen that only that part of the corona most distant from the centre (as at B) will receive even the whole of this light; and it is manifest from the figure that the nearer any part of the corona is to the centre (nearer C) the less light will it receive from the photosphere, so that the mean illumination of the corona by the photosphere is only equal to that which would be given by a ring $\frac{1}{2} \times 0''{\cdot}75 = 0''{\cdot}375$ wide.

Now, since the chromosphere extends from E towards F, the whole of the atmosphere producing the corona is illuminated equally by the chromosphere, and since the mean height of the chromosphere is much more than $0''{\cdot}375$, or other height deduced from the foregoing formula, it is quite possible that the dark lines of the spectrum coming from so small an area of photosphere may be blotted out, as Mr. Lockyer observes, by the light from a greater area of chromosphere wherever the chromosphere contains the proper substances; and it is probable that the vapours of a number of substances from the photosphere are carried up into the chromosphere in small quantities sufficient to obliterate the dark lines, since we find the vapours of magnesium, sodium, barium, and iron, sometimes in the chromosphere.

Although the total amount of light of all kinds given by an equal area of chromosphere is small compared to that given by an equal area of photosphere, still each particular kind of light from the chromosphere is as intense, or nearly so, as that particular kind of light from the photosphere, so that, if equal areas of chromosphere and photosphere be illuminating a part of our atmosphere, that part would give a spectrum, having its dark lines erased by the chromosphere, or a continuous spectrum. When the area of the photosphere is much less than that of the chromosphere, the bright lines given by the chromosphere would be much more visible than the remaining dark lines of the photospheric spectrum.

From this it appears that during totality we ought to get from the corona a nearly continuous spectrum, with bright lines given by the substances in the chromosphere. Some of the dark lines

of the photospheric spectrum ought to remain where the chromosphere does not contain substances giving bright lines in their place. Where the illuminating areas of the photosphere and chromosphere are equal, which is possible where the chromosphere is unusually low, we ought to obtain a spectrum as above, but without bright lines, the chromospheric lines being then only just able to obliterate the dark ones.

3. In the Indian eclipse Major Tennant saw a continuous spectrum without bright lines, which is that we should obtain on the above hypothesis, when the areas of chromosphere and photosphere illuminating our atmosphere are equal; but it is shown above that during totality with the ordinary height of chromosphere the illuminating area of chromosphere is much greater than that of the photosphere, so that the part of the chromosphere illuminating that part of the corona under examination must have been unusually low, or, as was probably the case, there were bright lines, for, as he says the spectrum was very faint, they may have been missed. There ought on this hypothesis to have been dark lines, but Major Tennant says that with so wide a slit he might have missed them. Prof. Pickering saw a continuous spectrum with bright lines, which is what we ought to obtain when the atmosphere is illuminated by a greater area of chromosphere than photosphere, as has been shown to be the case when the chromosphere is at its normal height. The dark lines which ought to have been visible on Mr. Lockyer's theory might possibly have been too faint to be noticed, since, as stated above, the area of photosphere in this case would be small in proportion to that of the chromosphere, so that the bright lines would appear very plainly when the photospheric spectrum was too faint to render the dark lines visible. As to the 1474 K line observed by Prof. Young to extend across the spectrum beyond the other lines of the chromosphere, Mr. Lockyer observes that he often sees this line and often does not, which appears fatal to this being a real corona line, as, if so, it ought always to be visible. Prof. Young also seems, in the note to his observations, to be doubtful how far this line extended from the prominence; and it is very probable that this line is either iron or hydrogen. There seems to be no evidence that the other lines seen in the corona spectrum are not chromospheric lines.

4. With regard to this point, an inspection of the figure will show that, as the Moon passes over the Sun, more photospheric light becomes available for illuminating the corona; but so long as the available area of the photosphere is less than that of the chromosphere, the dark lines of the spectrum, due to the photosphere, will be erased by the chromospheric lines (wherever the chromosphere contains the proper substances), and as the Moon moves forward the spectrum should on this hypothesis change, and when the illuminating area of the photosphere becomes greater than the area of the chromosphere, the dark lines of the photospheric spectrum should appear. It will also be seen that the

larger the illuminating area of the photosphere becomes the smaller will be the difference between the spectrum of the interior part of the corona and that of the exterior part, since, whatever be the extent of the illuminating surface of the photosphere, the exterior parts of the corona will only receive an excess of light over that received by the interior part equal to the amount of photospheric light received by those parts during totality, or, as in the case above taken, the excess will be equal to that given by a ring of light from the photosphere 0″·75 wide (or G E in the figure), so that, when a few seconds of photosphere are visible to the observer, the difference between the spectra of the exterior and interior parts of the corona would be inappreciable.

5. What spectrum ought the corona to give before totality on the following side of the Moon? In this case, when the angular distance of the limits of the Sun and Moon is some seconds, the difference between the spectra of the exterior and interior parts of the corona is small, since no part of the atmosphere in this case will be illuminated by the photosphere, so we ought to obtain a chromospheric spectrum, together with a faint photospheric one caused by a small amount of photospheric light reflected from the photosphere by the chromosphere.

6. On the foregoing hypothesis during totality the parts of the corona nearest the centre should give a different spectrum to the more distant portions, since the portions nearer the centre receive less photospheric light than the more distant parts, and the same amount of light from the chromosphere.

In order to test the correctness of this theory, advantage may be taken of the following facts:—1st. At that period of the eclipse when the limb of the Sun and Moon are in line with the observer, there will be a difference between the central and distant parts of the corona, and this difference will decrease as the Moon passes on, whereas, by the other theory, there should be the same difference as long as the corona is visible. 2d. If the corona be terrestrial, the spectrum of any portion of it ought to be continually changing during the passage of the Moon; but, if solar, the spectrum should remain unchanged.

On the Displacement of the Bright Lines in the Spectrum of the Solar Chromosphere. By G. M. Seabroke, Esq.

The author in reference to a letter of Father Secchi to the Academy of Sciences of 25th April, writes,—

"For some time past, Mr. Lockyer has been kind enough to allow me the use of his telescope and spectroscope to prepare myself for the observations I intend making during the ensuing eclipse; and as I have been using the same spectroscope with which the discoveries in question have been made, and which have been contested by Father Secchi, I think it right to add my independent testimony on that point."